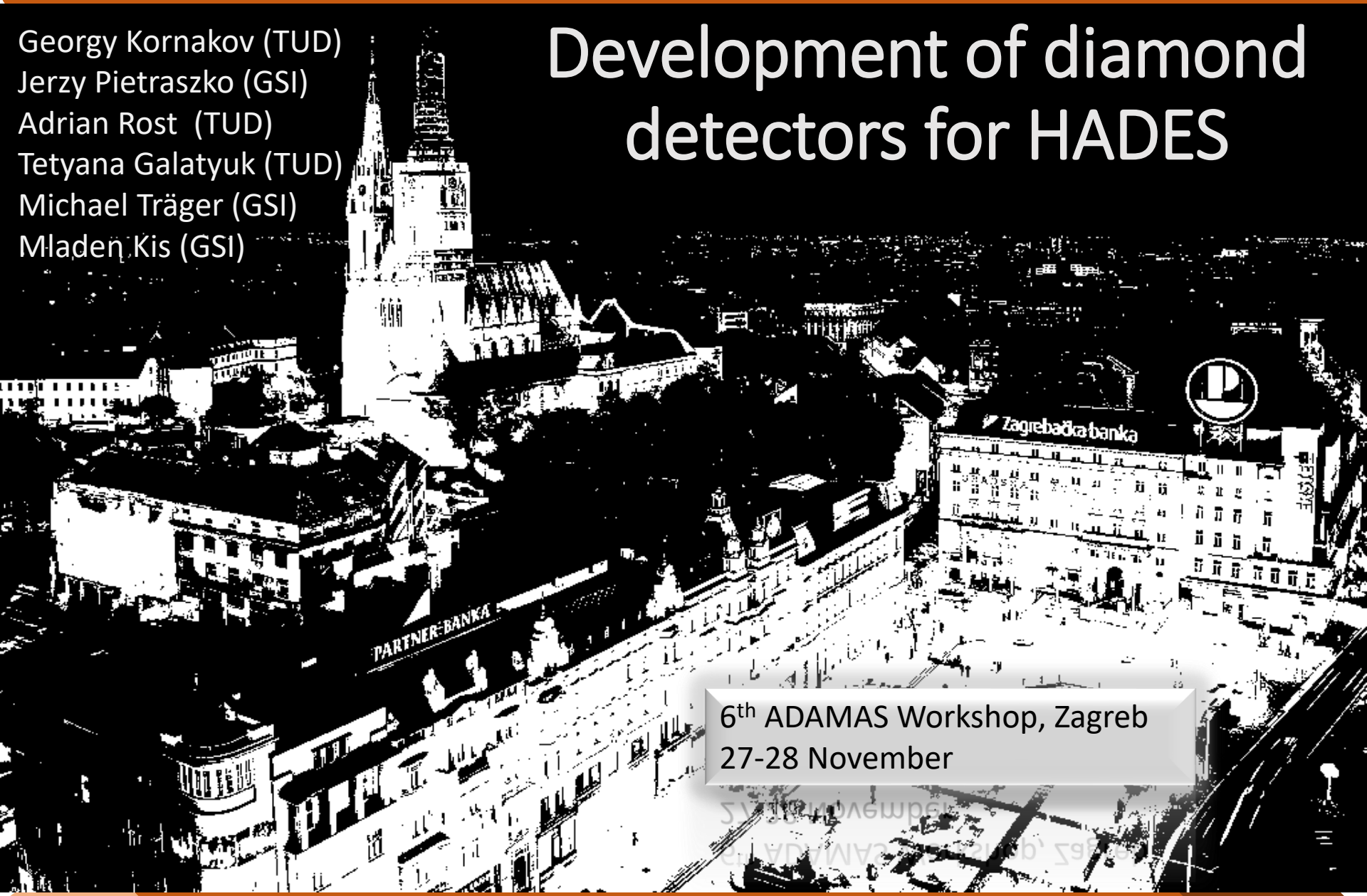
HADES

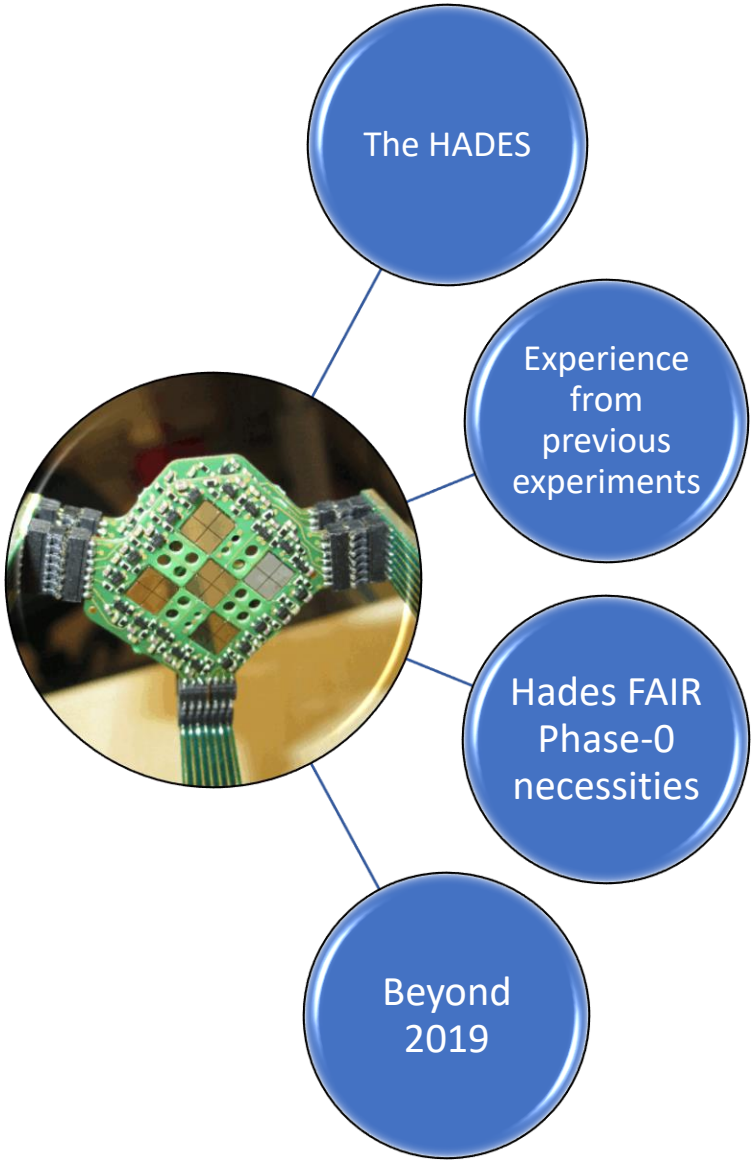
Development of diamond detectors for HADES

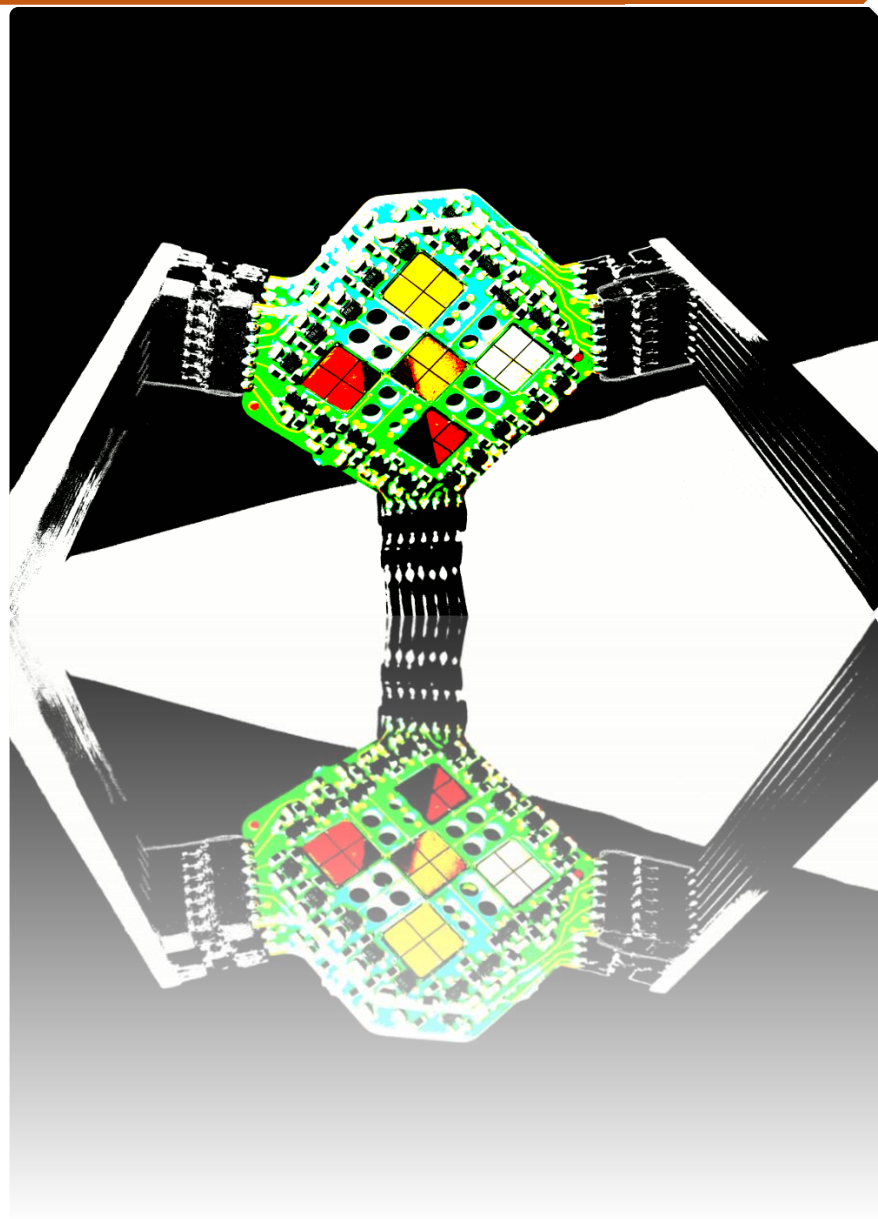
Georgy Kornakov (TUD)
Jerzy Pietraszko (GSI)
Adrian Rost (TUD)
Tetyana Galatyuk (TUD)
Michael Träger (GSI)
Mladen Kis (GSI)



6th ADAMAS Workshop, Zagreb
27-28 November

Outline


The HADES
Experience from previous experiments
Hades FAIR Phase-0 necessities
Beyond 2019



The HADES

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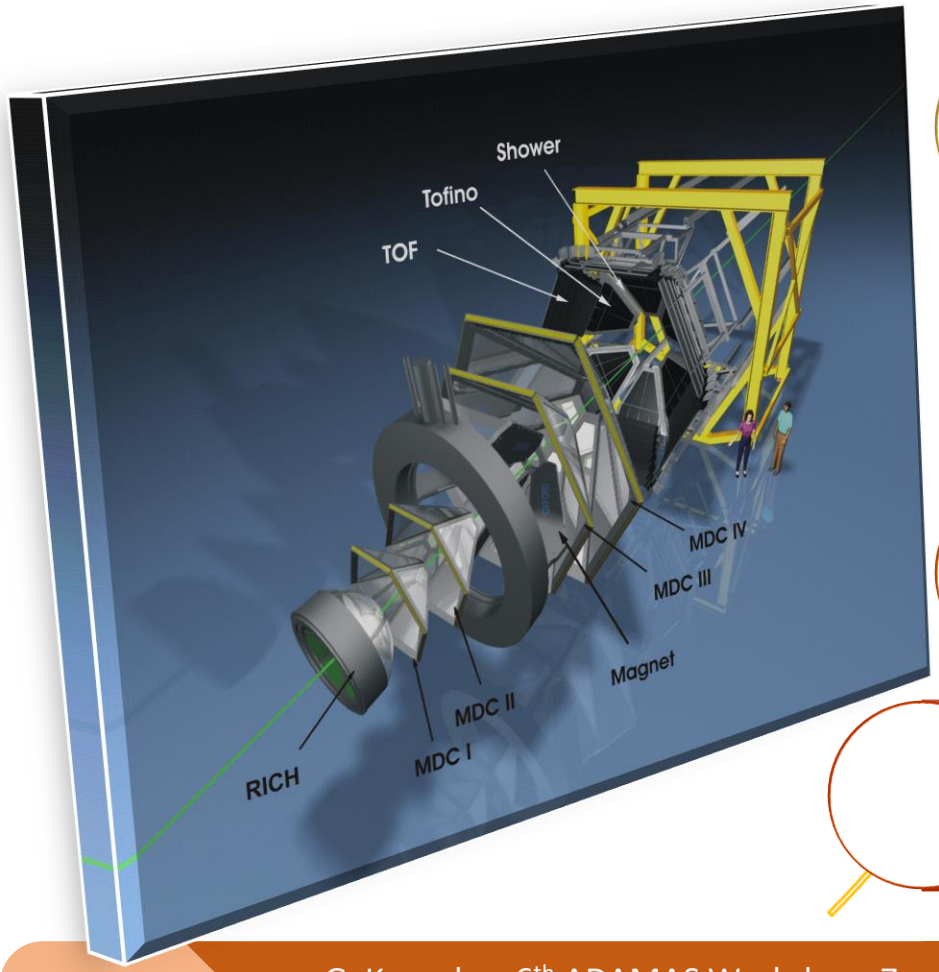

High Acceptance DiElectron Spectrometer

Fixed target @ SIS18 GSI
- 2π azimuth
- 15-85 Zenith

Elementary and heavy-ion beams

Rare probes
- Dileptons
- Sub-threshold strangeness production

Charged Particle Identification
- dE/dx
- Cherenkov + Electromagnetic Calorimetr
- Time-Of-Flight & momentum

Time-of-Flight

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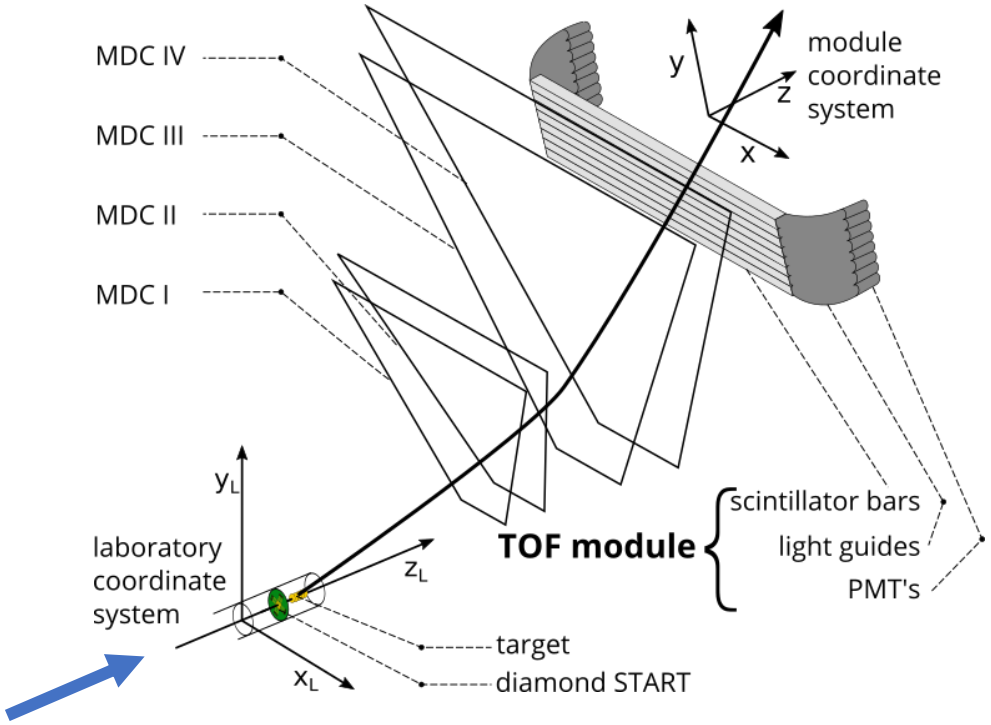
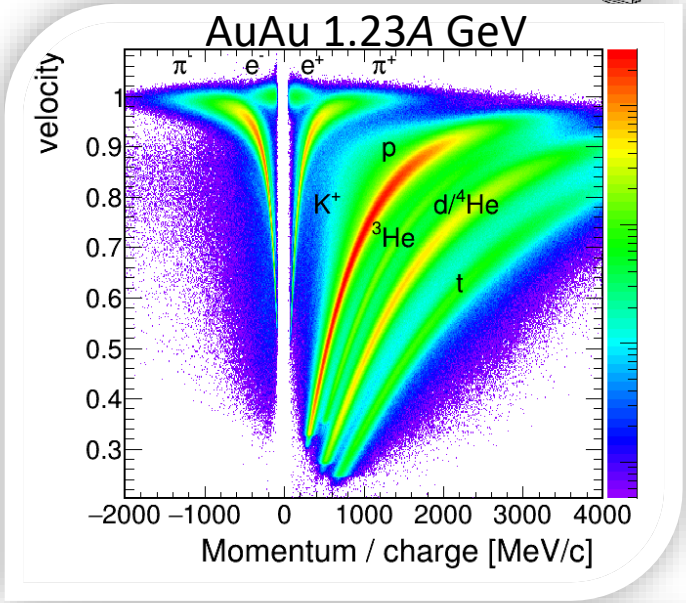
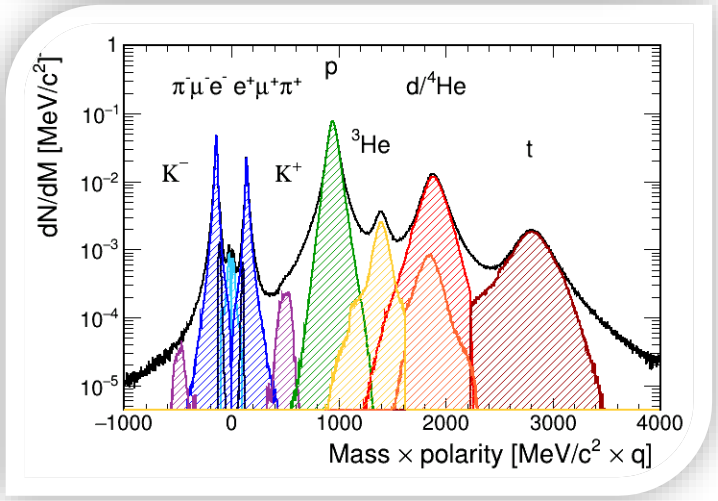
$ToF = T_{RPC/TOF} - T_{START}$ -> $\sigma ToF = \sqrt{\sigma T_{RPC/TOF}^2 + \sigma T_{START}^2}$

$\beta = ToF/path\ c$







Beam detector missions

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Accurate time measurement
σ_t< 100 ps

- T0 for RPC TOF Wall σ_t < 70 ps
- Scintillator TOF Wall σ_t 125-160 ps
- Reference time for all detectors

Beam counter
100 % efficiency

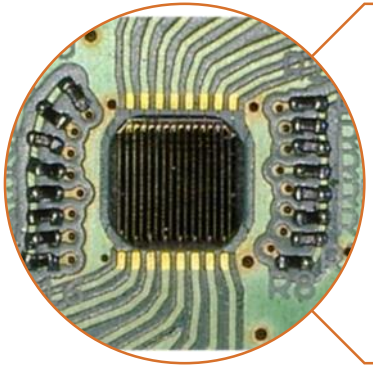
- Trigger
- Single beam particle counting: cross sections

Beam diagnostics
σ_x<2 mm high granularity

- Time profile
- Spatial profile
- Online focusing assistance

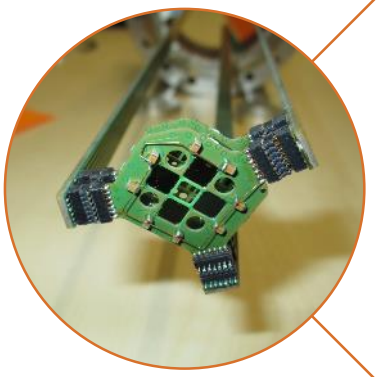
Event selection

- Pile-up rejection
- VETO of not interacted particles in target



Detector for Heavy Ions

- 4.7 mm x 4.7 mm surface
- 67 μm thickness
- 16-x 16-y strips
- 200 μm pitch, 90 μm gap



Detector for MIPs

- 4.5 mm x 4.5 mm x 0.3 mm scCVD high purity diamond material.
- Thickness of 300 μm , low Z
- In vacuum operation, without cooling, noise free
- 3x3 mosaic, 2 sides, 36 channles
- 12 mm x 12 mm total area

Au+Au at 1.23*A* GeV

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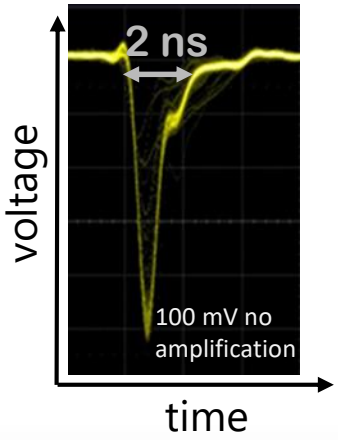
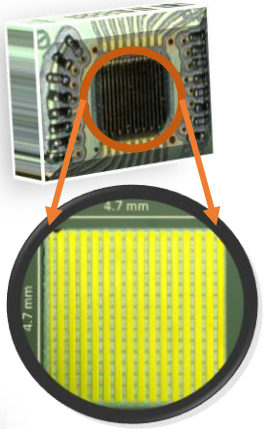
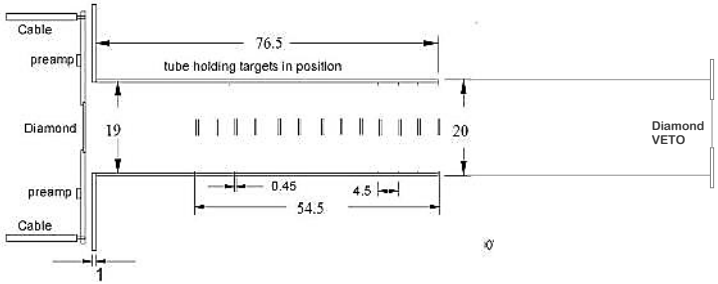
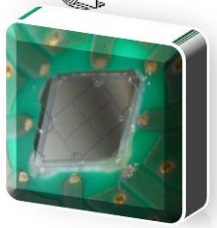
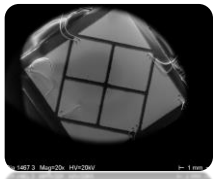


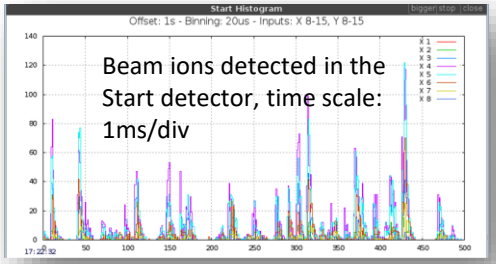


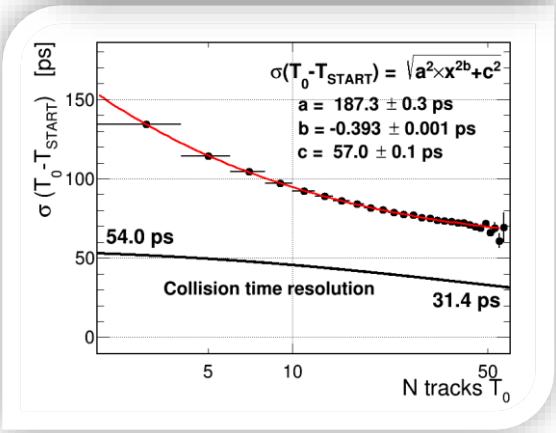
Beam size (3σ) 1.3 x 0.8 mm^2











Detector specs:

- scCVD diamond
- thickness 67µm
- Strip width 200 µm
- Gap width 90 µm

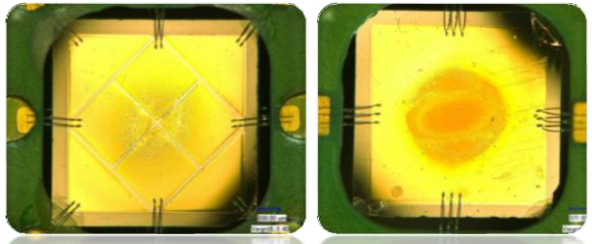
- size: 4.5 mm x 4.5 mm
- detector thickness: 70 µm
- detector time precision: ~50 ps

8 -segment detector

Dedicated electronics:

- Multi-hit TDC, 17 ps res.
- Detector resolution 42 ps

Mean 4-weeks Time resolution 54 ps
From analysis with high quality tracks



Irradiated by 3 x 10^{11} Au (1.23 AGeV) ions during 5 days

π^- PE/C/W with p = 0.7 GeV/c, 1.7 GeV/c

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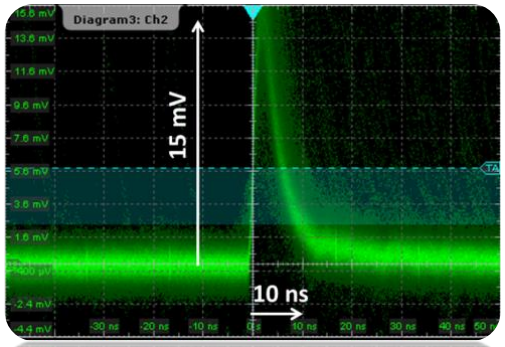
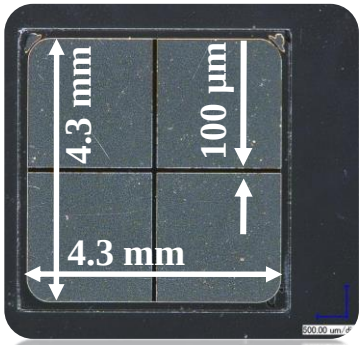
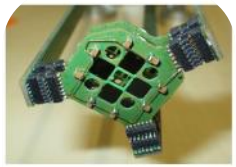
scCVD diamond signal for MIPs







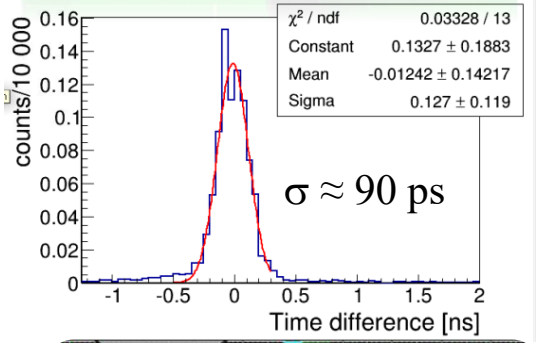
Requirements

- Time Resolution <100 ps
- Position Accuracy <2 mm
- High Effieciency & rate capability

Tech. solution

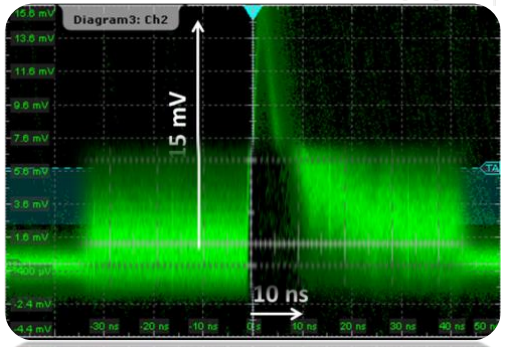
- Mosaic with 9 diamonds in two planes
- 4.6 x 4.6 mm2 and 300 µm
- 100µm space between electrodes
- four channels – metallization
- time resolution below 100 ps

p@ 2.95 GeV

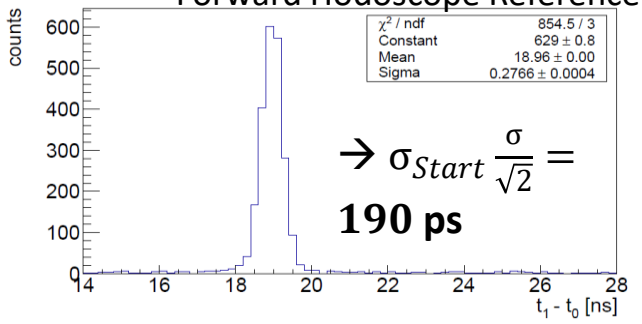


Performance in experiment:

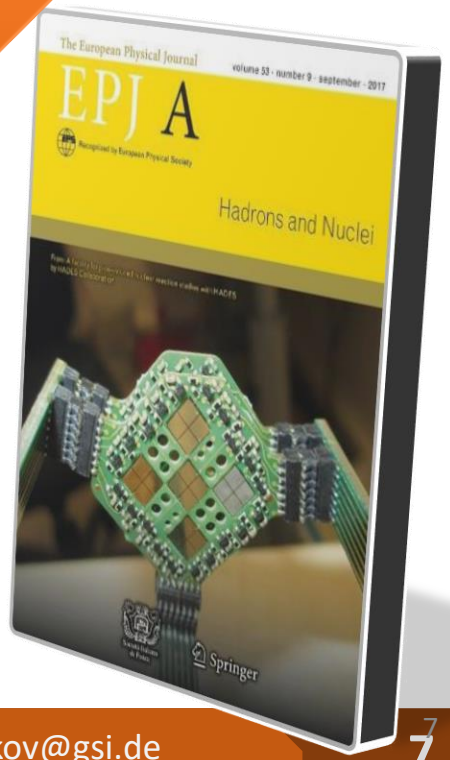
- 7 mv pick-up noise
- High Efficiency
- Slight time degradation
- ~200 ps Time resolution



Forward Hodoscope Reference



$\rightarrow \sigma_{Start} \frac{\sigma}{\sqrt{2}} =$ **190 ps**



HADES FAIR Phase-0 necessities

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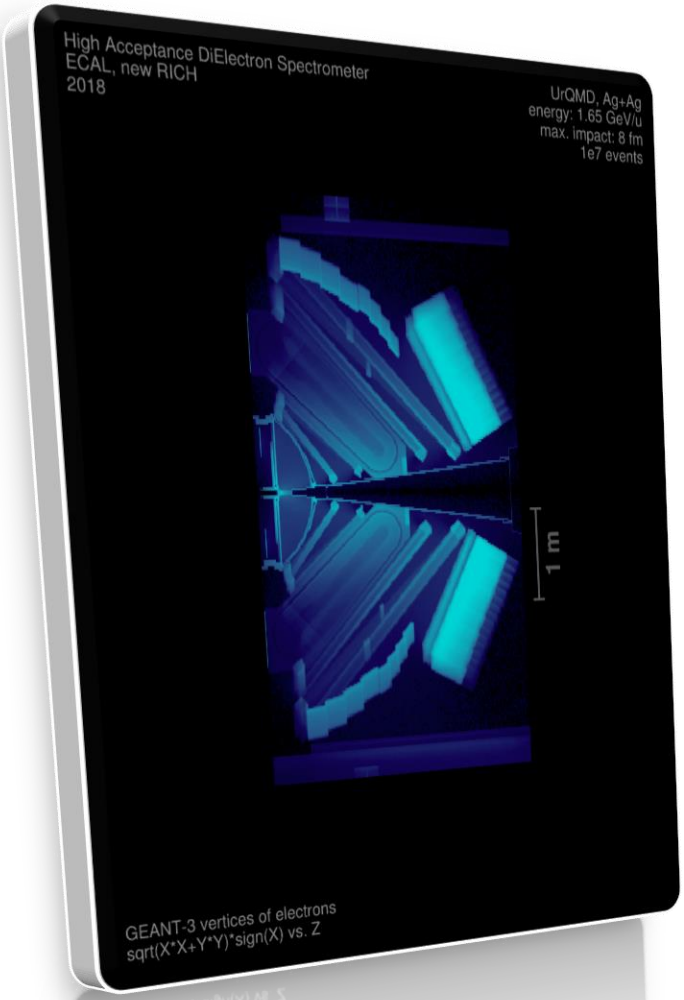

2018 Ag+Ag at 1.65*A* GeV

- scCVD for Ions
- 2-sides stripped detector
- 60 μm thinkness

2019 secondary 4 10^5 per spill π^- with p = 1.1 GeV/c

- scCVD for MIPs
- Mosaic of 9 diamonds in two planes
- 300 μm thikness

Beyond 2019

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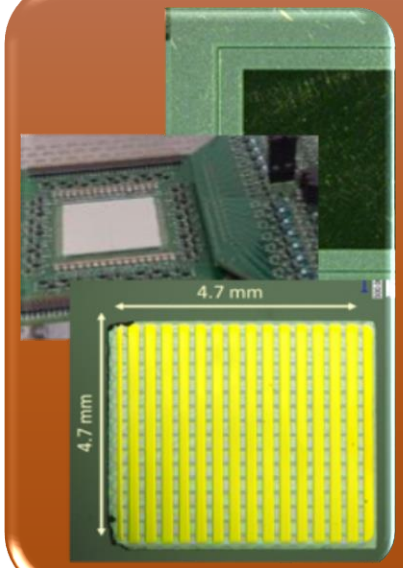
Proton beams

High intensity 10^8 s^{-1}

- 4.5 GeV/c
- p+p & p+A reactions: 1-2 % interaction prob.
- Di-leptons
- Double and triple strange particle production
- Cold matter effects
- Short Range Correlations

Requirements

- Timing < 100 ps
- 100 % MIPs efficiency
- Radiation hard
- Efficient trigger



Possible solutions

- Segmentation
  - Strips can be as small as 100 mm (Diamond as reference detector)
  - HPTDC limit: 10^6 channel/s
  - FPGA TDC TRB3 limit: 10^7 channel/s
- Efficient beam particle tracking
- Large Area
  - scCVD is Expensive
  - pcCVD for MIPs
  - Ultra Fast Silicon Detectors (UFSD)

Beam tracking for high rate experiments

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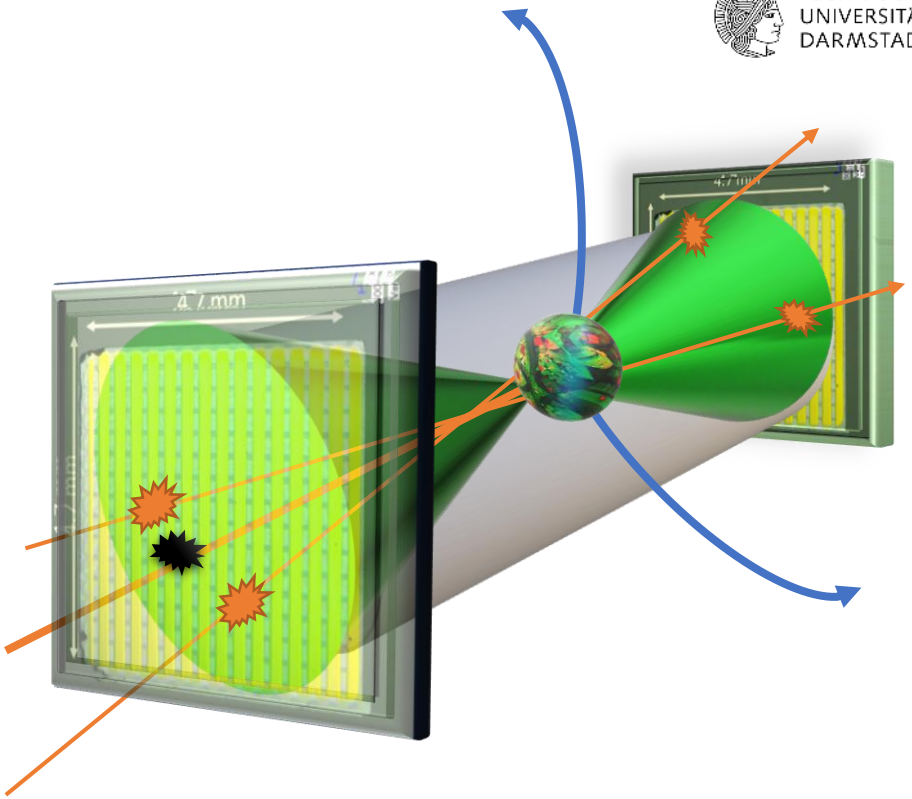
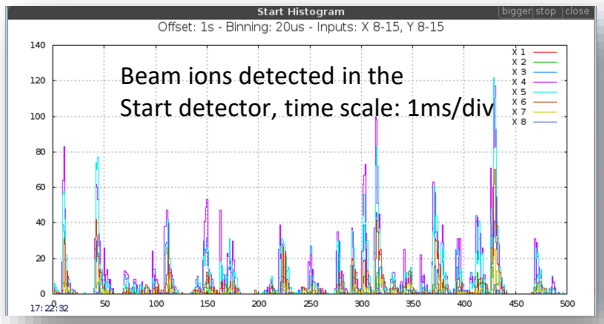
FPGA online particle rejection

10^8 particles 20% overlapping beam particles within 5σ

Efficient START-VETO system integrated into the trigger

10^6 T0 candidates after tracking





Significant improvement in T0 determination

Small size diamond based prototype detector in preparation

Needed area? Online T0 selection?

Alternative studies for beam detectors

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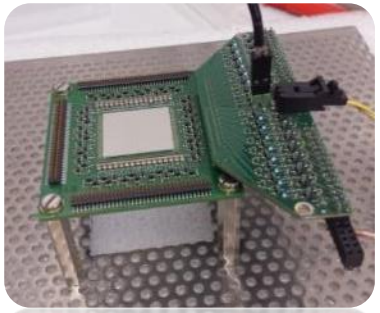
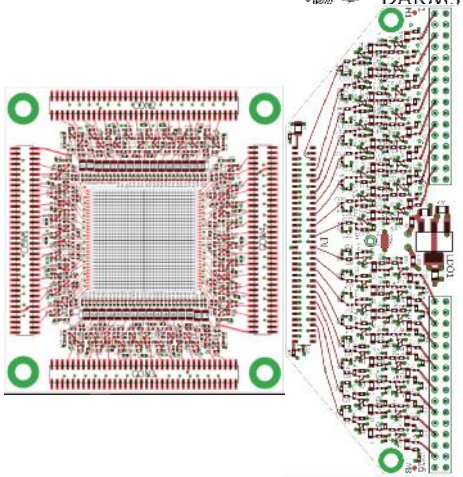
pcCVD For MIPs

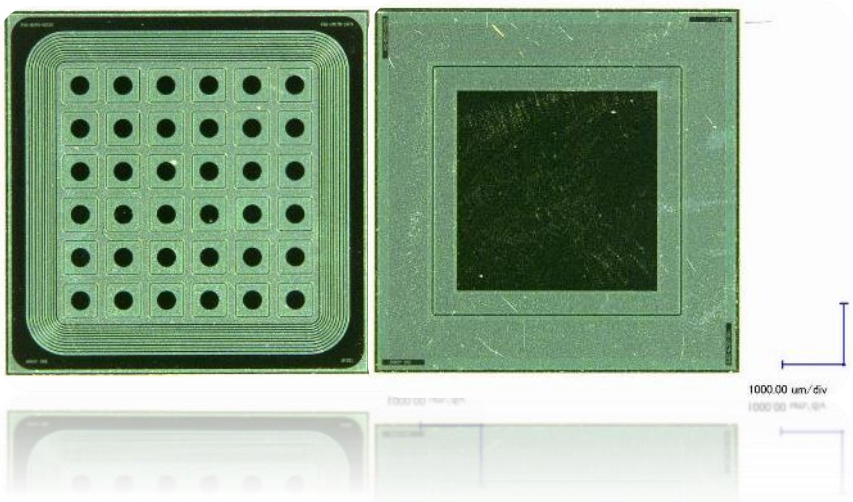
- 20 x 20 mm^2 pcCVD diamond with 128 stripes
- + Booster board (two stage amplifier based on transistors)
- 128 preamps top+bottom





Ultra Fast Silicon Detectors (UFSD)

- https://arxiv.org/pdf/1312.1080.pdf
- 25 ps time resolution
- Cheap: 12 x 3 cm x 3 cm = 5k€
- ATLAS HGTD(High Granularity Timing Detector)
  - 22 Institutes, 120 collaborators
- Issues:
  - radiation hardness
  - Readout/cooling
  - PCB in preparation



Summary

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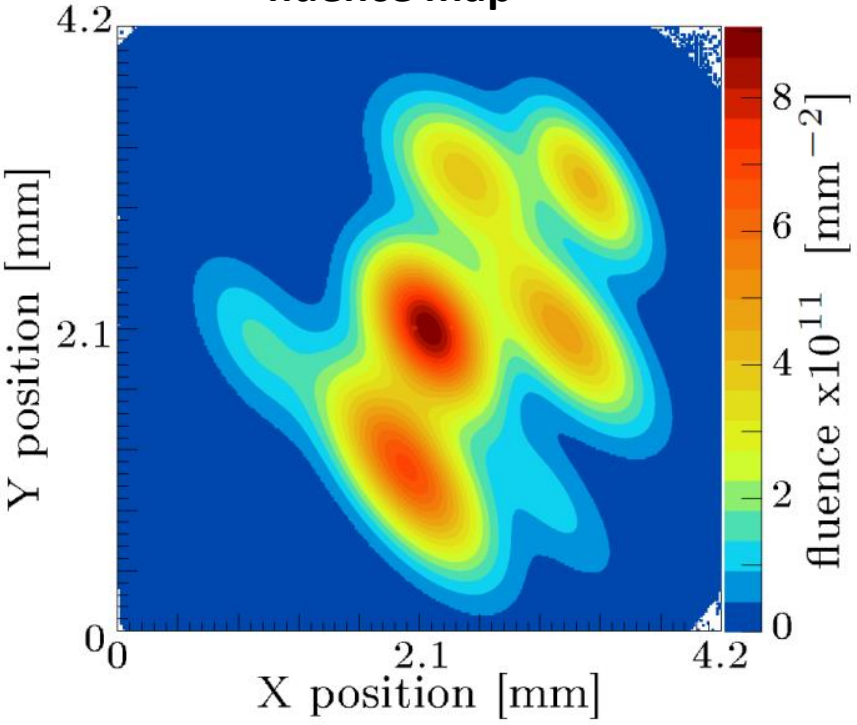
- The Hades beam detectors have shown a very good performance in experiments with Ions and MIPs
- The good time resolution for Ions allowed to obtain outstanding time-of-flight mesurement close to technical limits performance of all detectors combined.
- Diamons have shown good performance for MIPs. Although a slight time degradation due to pick-up noise was observed during experiments with the secondary pion beam.
- Developments for high segmentation/ large are diamonds are ongoing for future experiments with rates > 10^8 particles/s
- Other technologies based on pcCVD and UFSD are being evaluated as well as any other future alternatives to scCVD detectors that may appear.

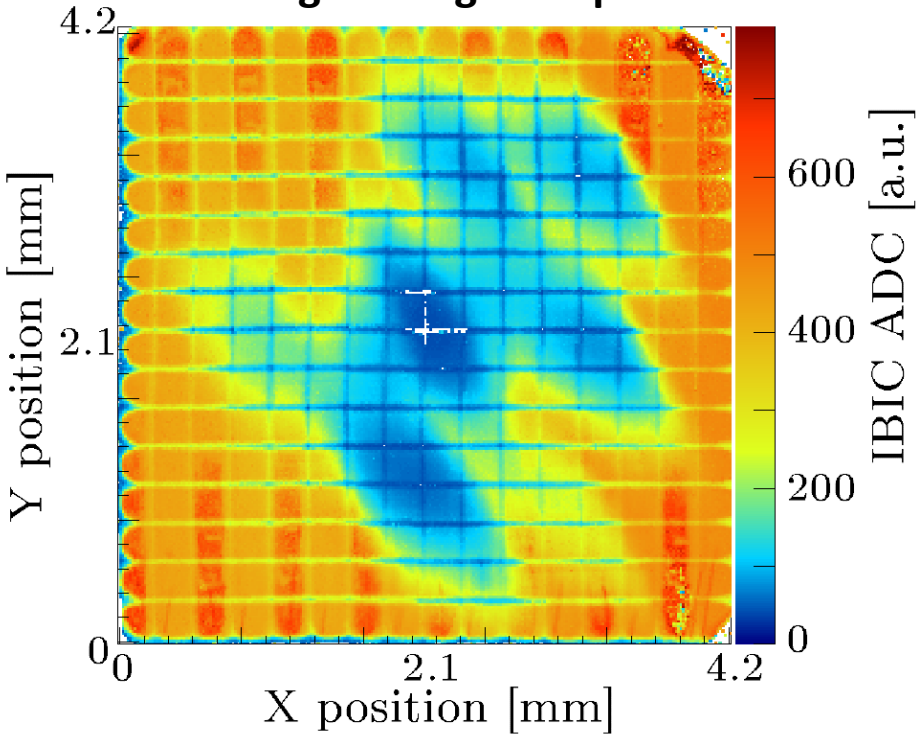
We are very greatful to the GSI Detector Lab for preparing the diamonds.

Thank you for your attention!

fluence map



signal height map



2D fitting of the Au hit distribution

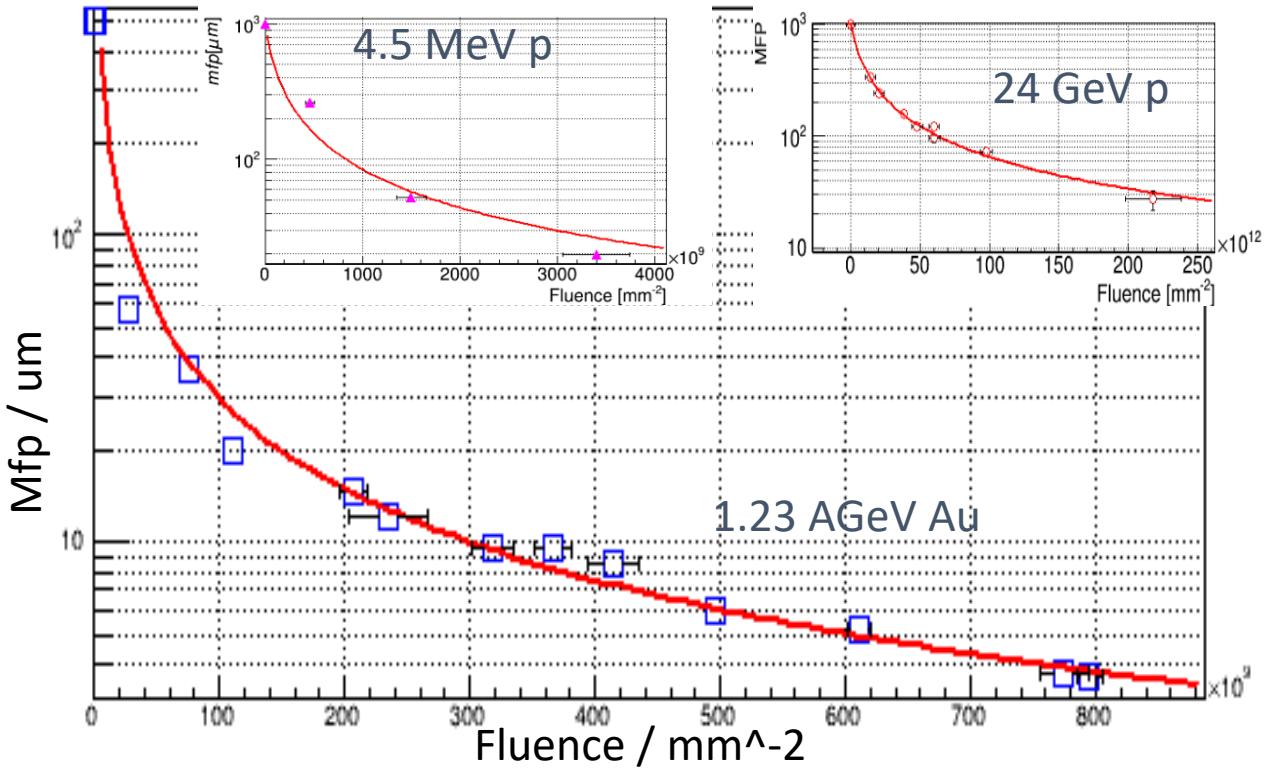
IBIC imaging with protons

Comparison with proton damage

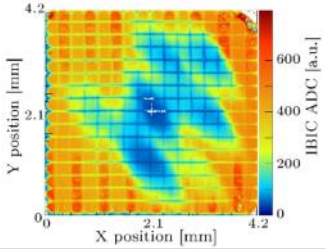
CCE → mfp (mean free path)

$$\frac{1}{mfp} = \frac{1}{mfp_0} + K \times \Phi \qquad K = \sigma \times k \times \frac{v_{th}}{v_d}$$

k is number of traps produced by 1 ion

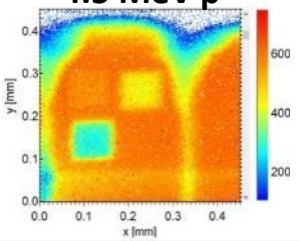


246.25 GeV Au



K = 3.4 x 10^{-7} µm

4.5 MeV p



K = 1.1 x 10^{-8} µm

24 GeV p

RD42 Collaboration

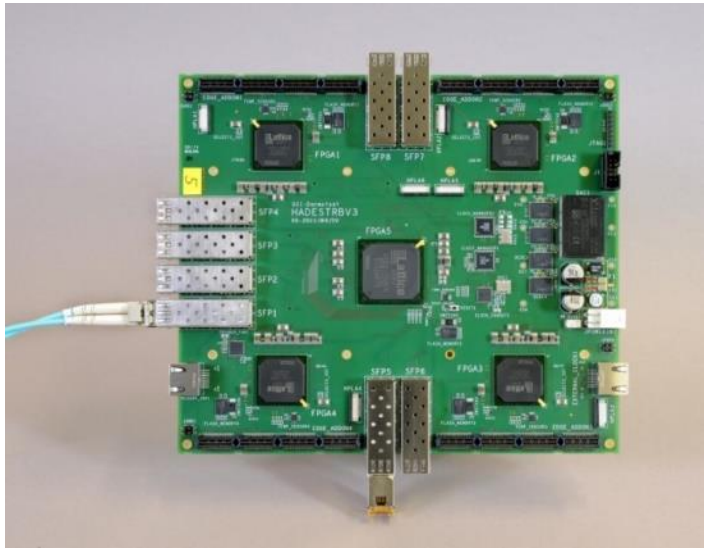
K = 1.4 x 10^{-10} µm

TRB3 platform

FPGA TDC and multi purpose DAQ

Time precision
10 ps RMS

4 FPGAs with
260 TDC channels



Single edge & ToT measurements

Usable in large systems & stand alone

50 MHz hit rate per channel

Only 48 V and GbE needed to take data

Internal trigger system and slow control

Expendable by Add-Ons and FEEs → i.e. PaDiWa

(developed at GSI, see: http://trb.gsi.de/)